Accelerator Systems Overview

Budget profile

Beam commissioning

Initial suite of 3 instruments

Additional instrumentation

Fundamental accelerator physics

LHC IR upgrade

Accelerator Systems topics in LARP Proposal

Program is truly multi-laboratory

Cross-integration between Instrumentation & Accelerator Physics activities

ACCELERATOR SYSTEMS TOPIC	page #	BNL	FNAL	LBNL
Hardware Commissioning	**15, 39**		Y	
Beam Commissioning	**15, 38**	Y	Y	Y
Initial Instrumentation	**37**			
Tune, Chromaticity & Coupling Feedbacl	16	Y	Y	
Real-Time Luminosity Measurements	16		Y	**Y**
Longitudinal Beam-Density Monitor	17	Y		**Y**
Additional Instrumentation	**37**			
Beam-Beam Compensation Systems	17	Y	**Y**	
High Frequency Schottky	17	Y	Y	Y
AC Dipoles	18	**Y**		
Fundamental Accelerator Physics	**38**			
Beam-Beam Interaction	18	Y	Y	Y
Electron Cloud	19	Y		Y
Other Vacuum Effects	19	Y	Y	
Remote Operations & Maintenance	19	Y		Y
LHC Upgrade Related Activities	**38**			
Interaction Region Optics	25	Y	Y	
Interaction Region Compensation	25	Y	Y	
Energy Deposition	26		Y	
Beam Loss Scenarios	27		Y	

Accelerator Systems budget profile

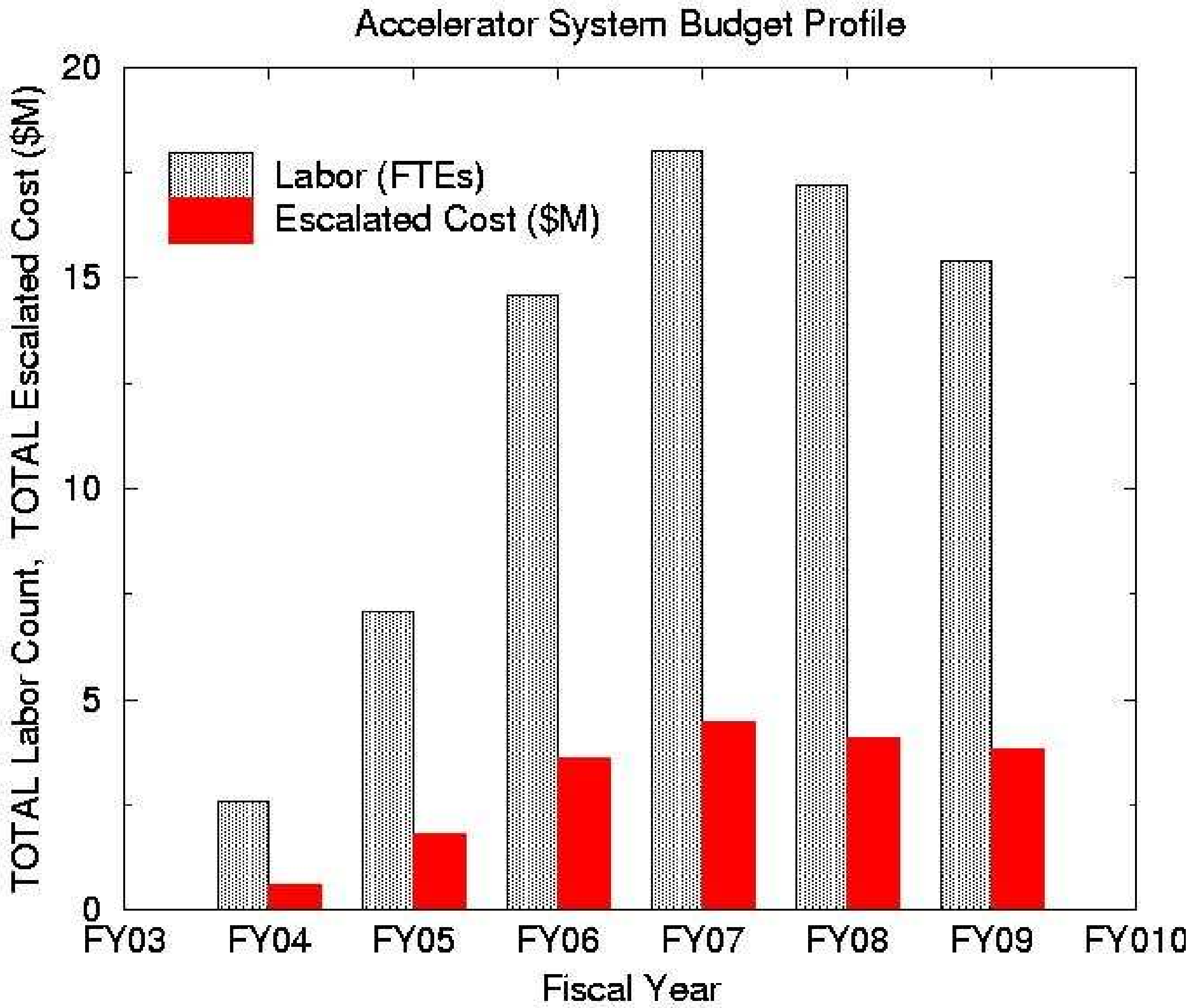
Accelerator Systems budget profile

The 3 Accelerator Systems areas:

1) Instrumentation

2) Beam Comm.
& Fundamental
Acc. Physics

3) Hardware
Commissioning



Accelerator Systems budget breakdown

		FY04	FY05	FY06	FY07	FY08	FY09
Labor Count	FTE	2.6	7.1	14.6	18.0	17.2	15.4
Labor Cost	$k03	502	1314	2410	2910	2676	2380
Travel	$k03	27	74	146	185	169	154
Materials & Services	$k03	90	330	760	865	690	690
TOTAL COSTS (escalated)							
Instrumentation	$k	300	744	1,733	2,048	1,953	1,897
Beam Comm & Acc Phys	$k	227	570	1,366	1,896	1,895	1,952
Hardware Commissioning	$k	111	509	525	512	249	0
GRAND TOTAL	**$k**	**638**	**1,823**	**3,623**	**4,457**	**4,098**	**3,850**
Guideline	$k	635	1,820	3,620	4,460	4,100	3,840

Assumes "3 lab average" labor rate, and naïve (minimal) travel rate per FTE per year

Beam Commissioning

Beam Commissioning

The LHC is complex & will be challenging to put into operation.

The participation of experienced U.S. scientists will speed up LHC commissioning, bring higher luminosity earlier

Participation is also a direct benefit to the U.S. programs, since commissioning colliders is a once-in-a-decade opportunity.

Maintaining a core of (young) experience is vital for the present and future capabilities of hadron colliders in the U.S.

Beam Commissioning
How?

CERN is receptive: the consensus with Bailey, Collier, and Myers is to support 1 scientist per commissioning shift

- ideally: 12 FTEs
- guideline budget: 9.5 FTEs

Staff these shifts with a combination of visits:

- long (up to a year)
- relatively brief (as short as a month)

"Breadth and depth": the very best semi-junior physicists, as well as more senior experienced physicists.

Beam Commissioning
When?

Still must work out in detail how this will be done:

- integration with the CERN teams must begin well before first beam (injection test)
- compare with detector groups planning for remote groups to have system responsibilities

Beam Commissioning:
What is a "system"?

LARP Beam Commissioners must have specific responsibilities:

- "System Commissioners" (integrators) in RHIC parlance
- "Mr. X" in LEP operations parlance

Initial instruments are natural examples of a "system"

- a LARP Beam Commissioner may be an Instrumentation Physicist or an Accelerator Physicist
- but he/she pulls shifts, as a peer, in the Control Room
- instrument or not, the goal is "end-to-end" responsibility

Where are the boundaries of responsibility? Low/high level controls? Need more discussions with CERN ...

Initial Instrumentation Suite

Initial Instrumentation Suite

All three initial instruments are needed for efficient LHC beam commissioning, and early high performance

They have been initially approved by the Program Leader with advice from the U.S. - CERN Steering Committee, with a refined approval of a more detailed plan yet to come

They push the state-of-the-art

In some cases their development will also contribute to the efficient operation of RHIC and the Tevatron

Initial Instrumentation Suite

1) Tune, Chromaticity, & Coupling Feedback

- crucial for efficiency with intense beams suffering dynamic effects during & after injection, & all the way up the ramp
- collaboration meeting on this topic, Fermilab, May 9 2003

2) Real-Time Luminosity Measurements

- help keep the beams in exact collision.
- assuming gas ionization technology, we will deliver the R&D on a time scale consistent with first collisions

3) Longitudinal Beam Density Monitor

- vital, with 350 MJ of stored beam energy
- observe fast (sub synchrotron period) beam dynamics

Additional Instrumentation

Additional Instrumentation

"Additional instruments" are more technologically speculative

- decide which devices to support “at the appropriate time”

- potential examples:
  1) Beam-Beam Compensation Systems,
  2) High Frequency Schottky Monitors,
  3) AC Dipole,
  4) Consumable collimators (SLAC),
  5) ZDC Heavy Ion lumimonitors (DOE/NP)
  6) .....

Fundamental Accelerator Physics

Fundamental Accelerator Physics

Beam-Beam Interaction

- RHIC: strong-strong, Tevatron: Electron Lens, LBL: sims

Electron cloud and other vacuum effects

- RHIC & the Tevatron as cryogenic test beds. Synch light.

Remote operations & maintenance

- work with REAP, GRID, and MVL efforts

LHC upgrade optics

- synergy with magnet program

Interaction Region compensation

- before & after upgrade

Energy deposition and beam loss scenarios

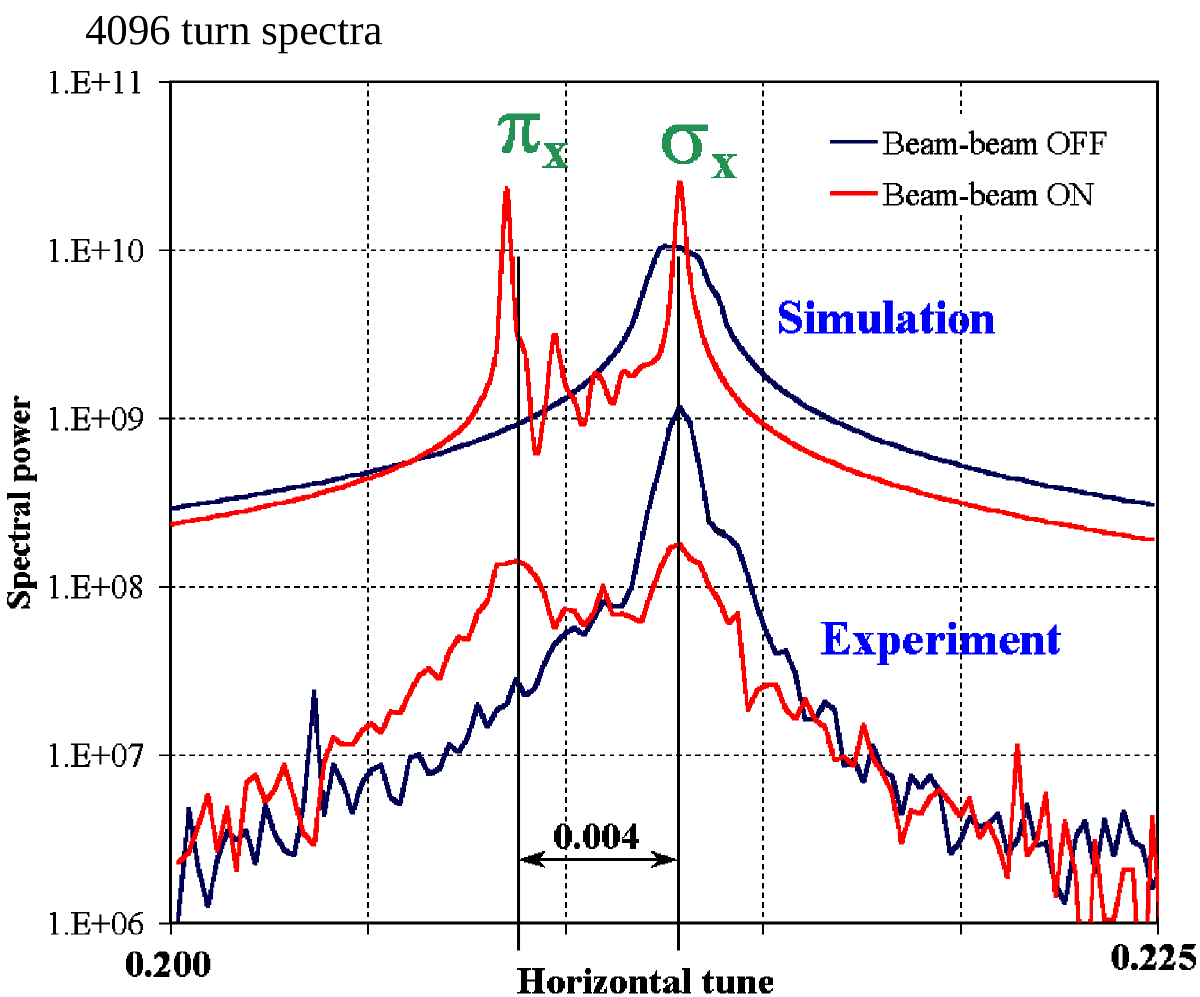
- before & after upgrade

US LARP

Beam-Beam Interaction

Strong-Strong experiment & simulation (RHIC)

Data: Fischer et al (BNL). Simulation: M. Vogt et al., DESY



RHIC is first hadron collider to see strong-strong modes!

Experiment:
- single p bunch/ring
- ξ = **0.003**

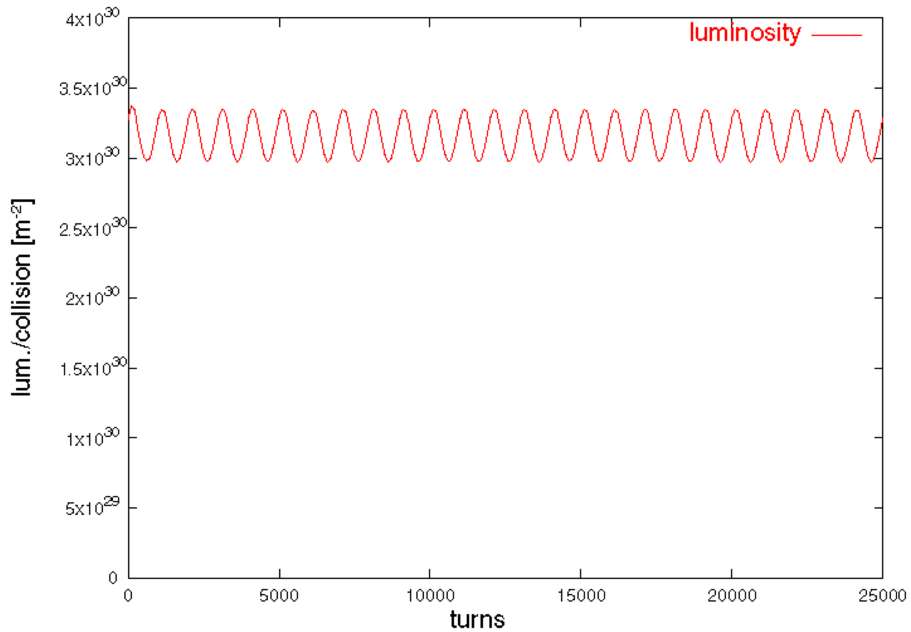
-**Observation:**
- π_x-mode shift: 0.004
- expectation:

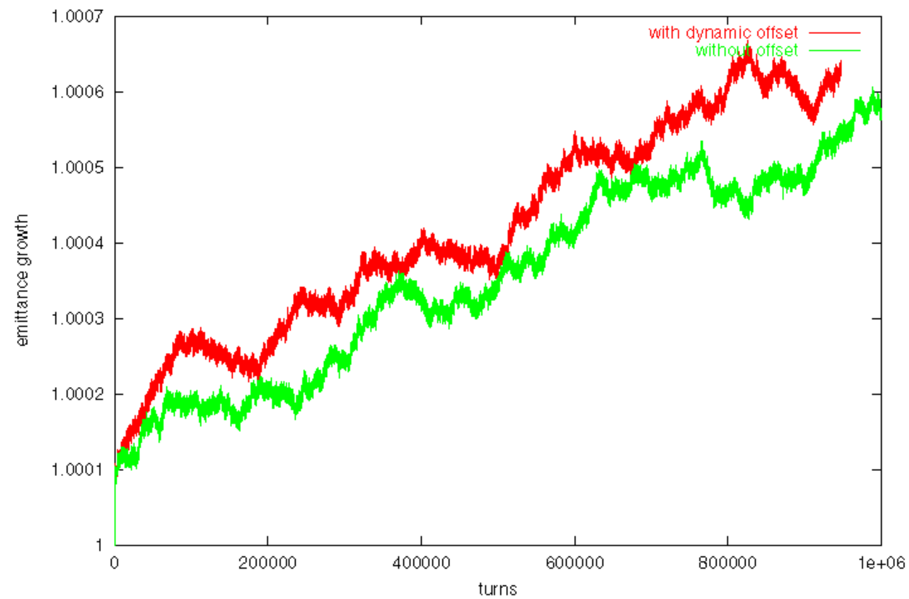
  $1.21 \cdot \xi = 0.0036$

[Yokoya, Meller, Siemann]

Beam-Beam
Simulated influence of wobbling

Simulation: J.Qiang, LBNL





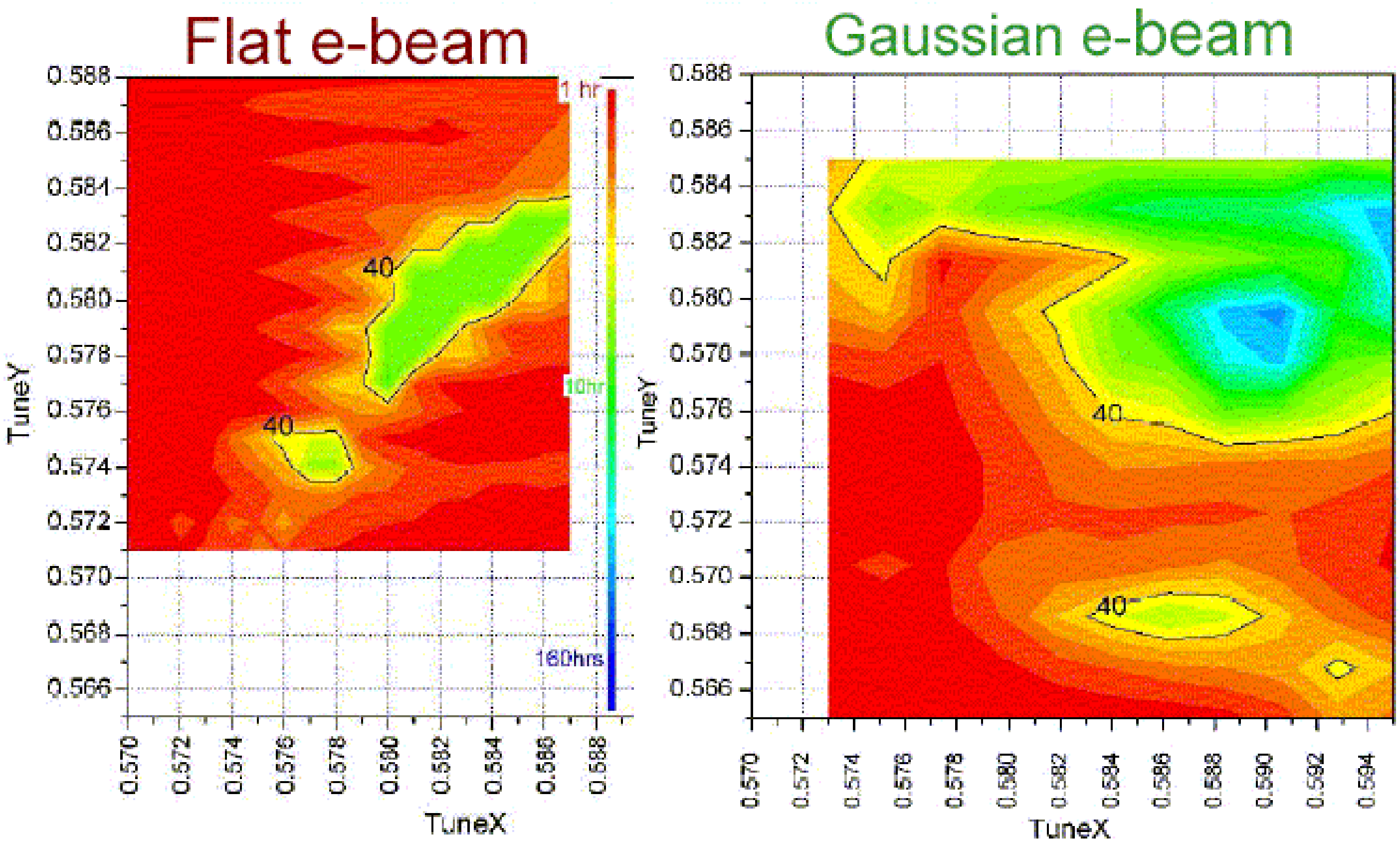
Luminosity per collision vs. time during circular sweeping in the lumimonitoring scheme being developed at LBNL

Emittance growth in a strong-strong beam-beam simulation.
Green head-on BB collisions
Red with 0.1 sigma wobbling

Beam-Beam
Lifetime vs tunes with Tevatron Electron Lens

Data: V. Shiltsev, FNAL

TEL tune shift of 0.004

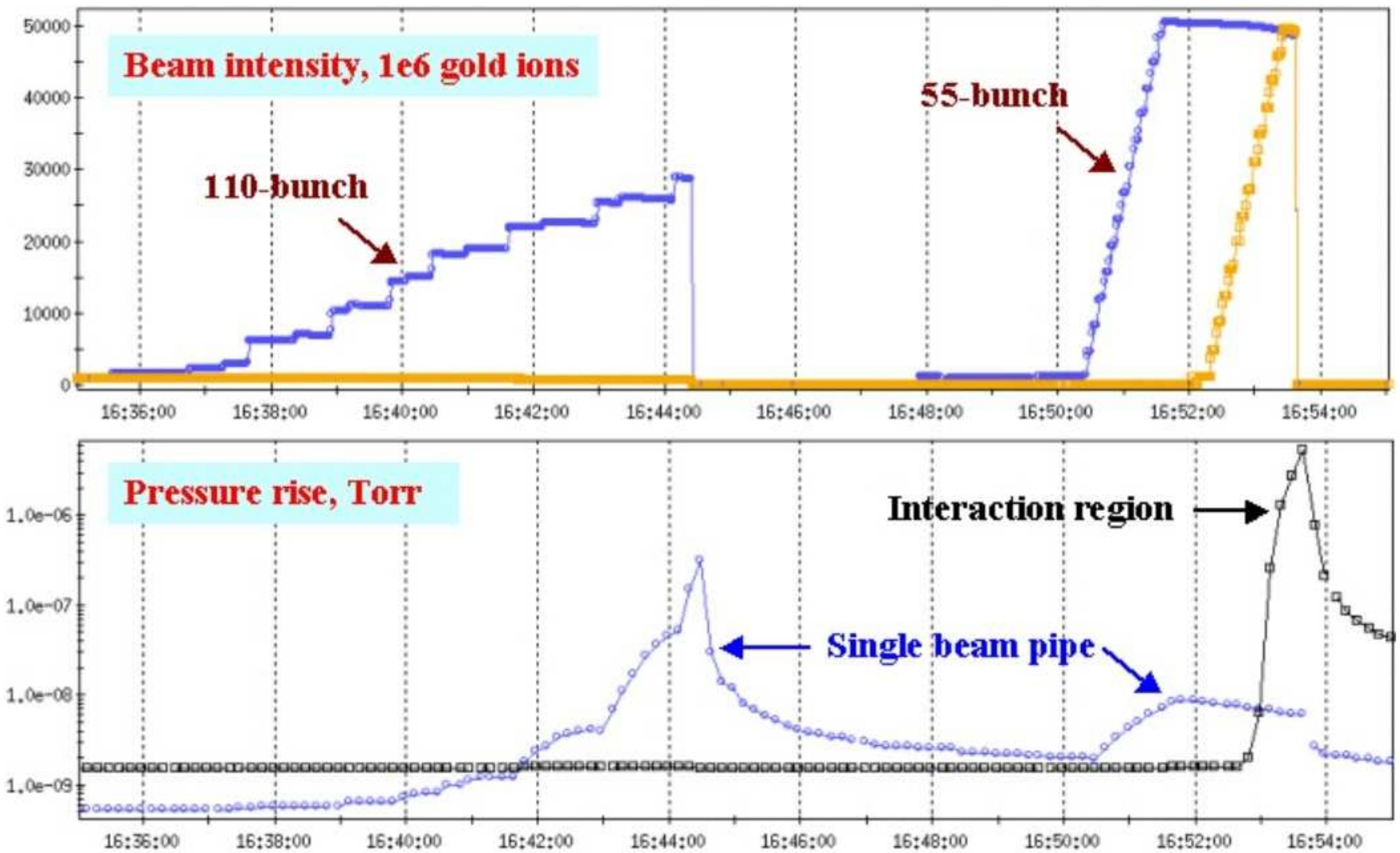


New Gaussian profile gun is much more promising ... ?

Electron cloud and other vacuum effects

Data: Zhang, Fischer et al, BNL

RHIC suffers, but not the Tevatron



Destructive RHIC pressure rise in warm sections in both rings

Remote Operations and Maintenance

The relevance is clear, although the technology is still in rapid motion

- CMS Virtual Control Room
- GRID, MVL

Remote control room scenarios:

- symmetric synchronous
- symmetric sequential
- asymmetric

For LARP, asymmetric:

"Don't duplicate the entire control room, just enough identical displays, plus presence"

LHC IR upgrade

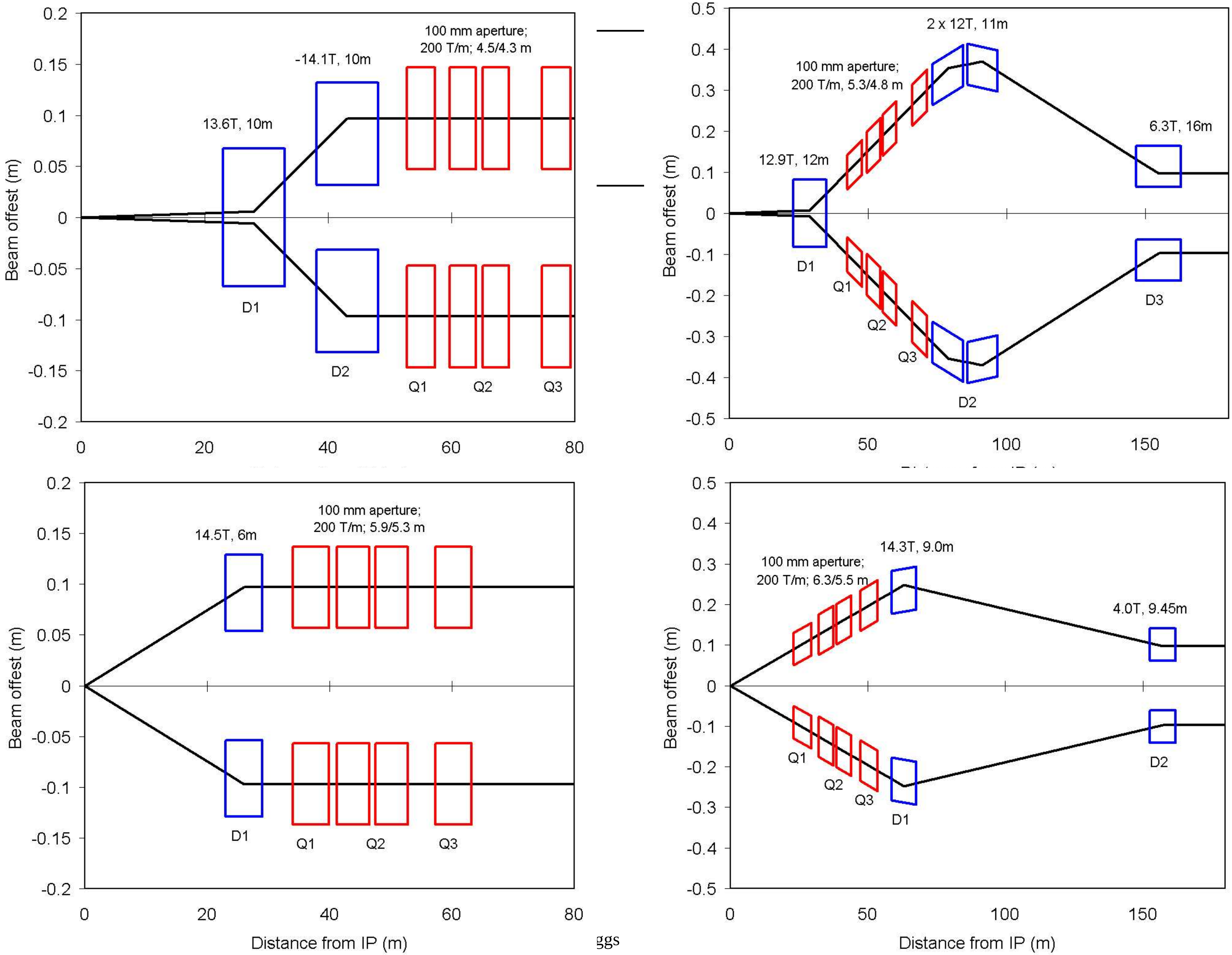
LHC upgrade optics

In principle there are many upgrade possibilities on the table ...

Table 2: Beam parameters for different LHC upgrade

Scenario Ref.	Remarks	E [TeV]	Ib [mA]	nb [-]	σ_z [mm]	Luminosity [cm-2.s-1]
A	Nominal	7	0.20	2808	77	1.00E+34
A'	Ultimate	7	0.30	2808	77	2.31E+34
A"	Modest upgrade	7	0.30	2808	38.5	4.63E+34
Bbb	With bunched beam	7	0.30	5616	38.5	9.25E+34
Bsb	With super-bunch	7	1029	1	75000	9.40E+34
B'	Strong bunches	7	0.48	2808	77	8.70E+34
Cbb	With bunched beam	14	0.14	2808	54.4	1.00E+34
Csb	With super-bunch	14	75.6	1	8250	1.00E+34
Dbb	With bunched beam	14	0.23	5616	54.4	1.00E+35
Dsb	With super-bunch	14	720	1	75000	1.00E+35

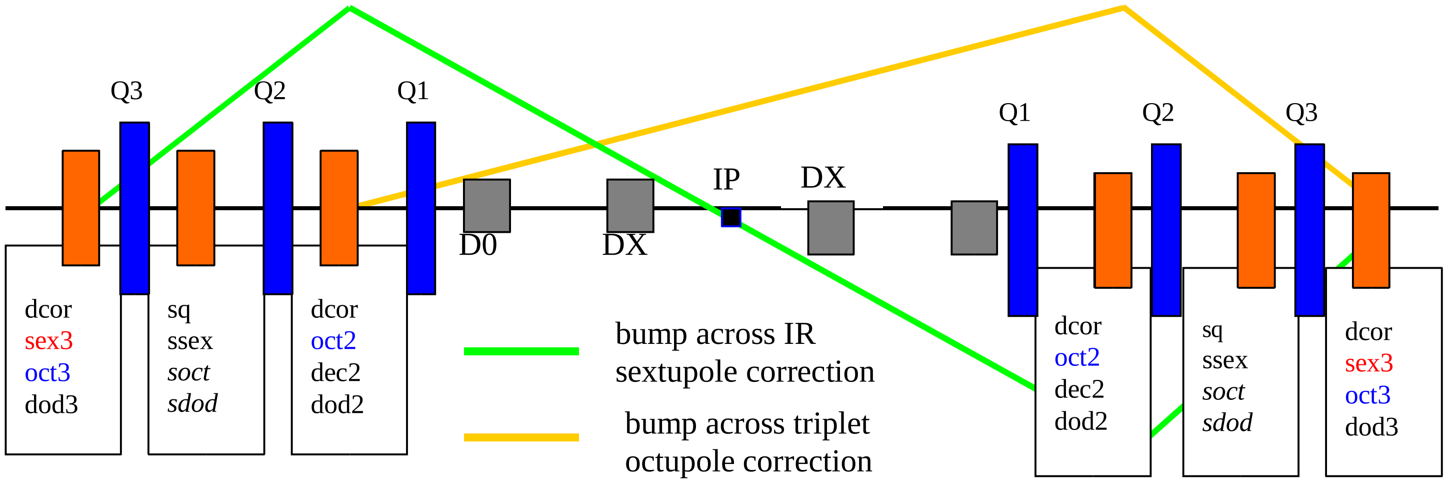
... but in practice only IR upgrades are "this side of the horizon"



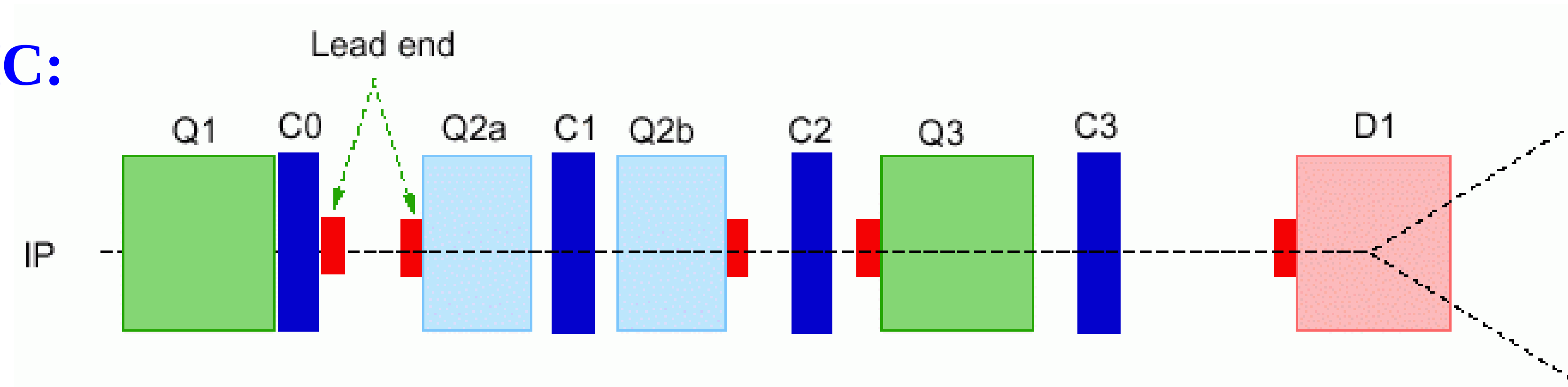
13.6T, 10m
-14.1T, 10m
100 mm aperture;
200 T/m; 4.5/4.3 m
D1
D2
Q1
Q2
Q3
Beam offest (m)
2 x 12T, 11m
100 mm aperture;
200 T/m, 5.3/4.8 m
12.9T, 12m
6.3T, 16m
D1
Q1
Q2
Q3
D2
D3
Beam offest (m)
14.5T, 6m
100 mm aperture;
200 T/m; 5.9/5.3 m
D1
Q1
Q2
Q3
Beam offest (m)
Distance from IP (m)
100 mm aperture;
200 T/m; 6.3/5.5 m
14.3T, 9.0m
4.0T, 9.45m
Q1
Q2
Q3
D1
D2
Beam offest (m)
Distance from IP (m)

Interaction Region compensation
RHIC -> LHC -> Upgrade

RHIC:



LHC:



Energy deposition & beam loss scenarios

The large stored energy (350 MJ) in the LHC beam will provide many operational problems

- analysis of energy deposition effects is ongoing
- strong technical expertise at Fermilab
- IR magnet heat load problem gets worse in an upgrade

Gradual beam loss from intended buckets into abort gap

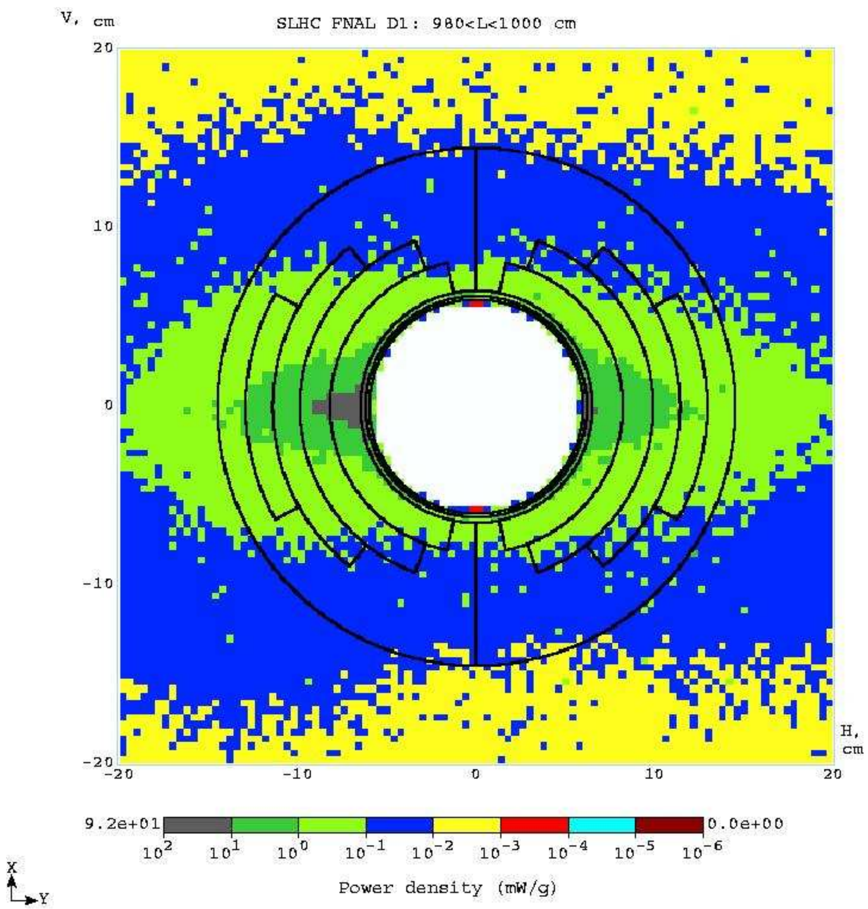
- can cause quenching during beam dump/abort
- is not well understood (cf Tevatron)
- is amenable to study with Longitudinal Density Monitors

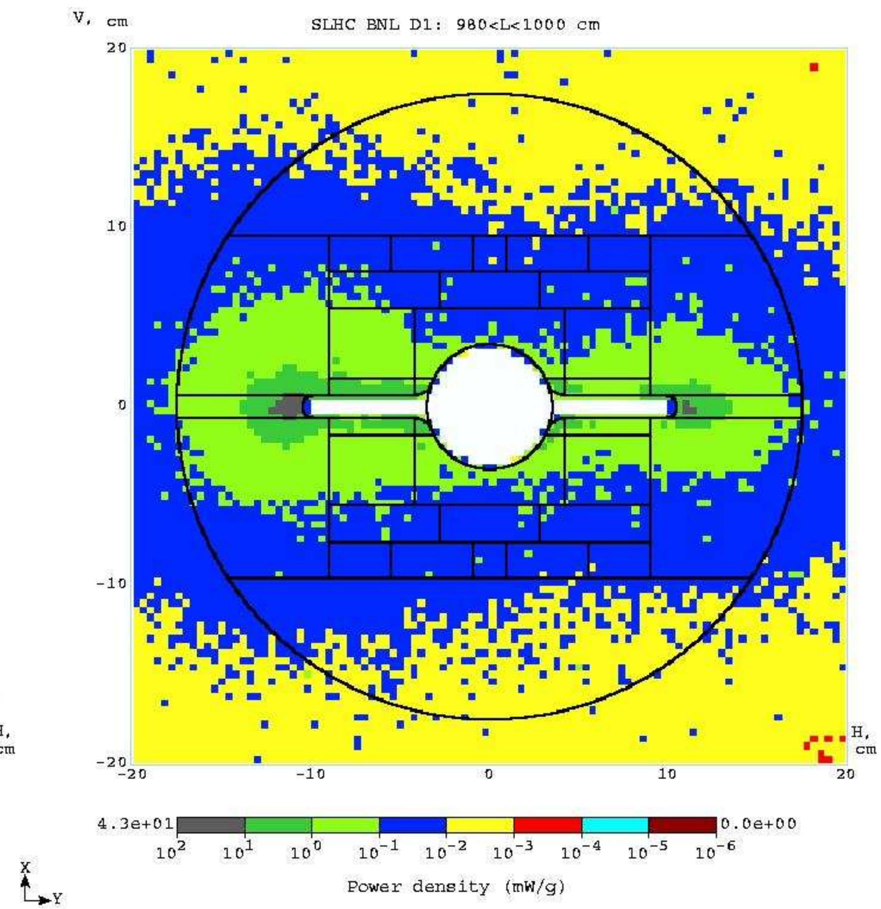
Energy deposition

D1 in a "dipoles first" upgrade scenario

MARS data: Mokhov et al, FNAL

Will the first beam splitting dipole survive?   3.5 kW per magnet?





Summary – 1

Maximize early HEP output

- while advancing U.S. accelerator science & technology
- integrate AP, IP, & Engineering topics, at all 3 U.S. labs

Budget profile "plateaus" at about 17 FTEs, 4 M$ per year

- Instrumentation

  3 Initial, then Additional Instruments

- Beam Commissioning

  (see below)

- Fundamental Acc Phys

  FY04: level of effort activity for unique US capabilities

- Hardware Commissioning

Summary – 2

Beam Commissioning

- control room shifts by Acc. & Instr. Physicists
- integration with CERN teams must begin early
- Beam Commissioners will have system responsibilities

  eg "end-to-end" integration of initial 3 instruments
- where are the boundaries, etc? More discussion needed